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ABSTRACT

The Personalized System of Instruction (PSI) represents an alternative method of instruction to both conventional lecturing and programmed learning. The purpose of this paper is to report on an experiment in which the PSI technique is employed on a microeconomics course in which a one semester introductory course was a prerequisite and was conducted in a small liberal arts college. A total of 92 students were allocated to three sections of microeconomics. Two of the sections were taught in a conventional lecture format and the final section was taught in the PSI format. All three sections met for two one and one half hour periods a week. Each student was exposed to the same body of material. The course was based on a conventional text that all sections used. The PSI section had the text supplemented by written handouts that consisted of the kind of elaboration and clarification that would ordinarily occur in a lecture. The output of the testing was based upon two instruments, the final examination and the course evaluation. Among the conclusions is that the PSI method does provide an alternative educational option that, while not dominating the other methods, does seem to offer students a choice which they value. Used prudently the PSI method can make a valuable addition to the teaching techniques of economics. Tables related to the text are included. (Author/PG)

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# TEACHING INTERMEDIATE MICROECONOMICS USING THE PERSONALIZED SYSTEM OF INSTRUCTION: AN EVALUATION

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TABLE OF CONTENTS

Section Page

I. INTRODUCTION..... 1

An Overview
The Nature of the Personalized System of Instruction

II. THE NATURE OF THE EXPERIMENT..... 5

Background
An Overview of the Experiment
The Final Examination
The Course Evaluation
Potential Biases in Interpreting the Results
Profile of the Sample

III. AN ANALYSIS OF THE OUTPUT MEASURES..... 14

Student Performance
Student Perceptions of Their Educational Experience
Timing Flexibility
Student-Faculty Interaction

IV. AN ANALYSIS OF THE INPUTS..... 30

Faculty Time
Student Time
Costs

V. SUMMARY AND CONCLUSIONS..... 36

APPENDIX A. ..... 39

The Williams College Course Evaluation

# LIST OF TABLES


| TABLE Number | | Page Number |
|---|---|---|
| I. | Mean Values of Selected Student Characteristics for Lecture and P.S.I. Sections | 13 |
| II. | Estimates of the Parameters of a Linear Model to Predict Final Examination Scores | 16 |
| III. | Estimated Percentage Improvement in Final Examination Score Resulting from P.S.I. for Students of Differing Abilities | 18 |
| IV. | Estimated Percentage Improvement Attributable to the P.S.I. Method by Students of Differing Abilities on Component Parts of the Final Exam | 21 |
| V. | Student Perceptions of Their Educational Experience in the P.S.I. and Lecture Sections | 24 |
| VI. | Student Perceptions of Their Degree of Motivation in the P.S.I. and Lecture Sections | 25 |
| VII. | Percentage Responses on Desired Teaching Technique for P.S.I. and Lecture Sections | 26 |
| VIII. | A Comparison of the Degree of Participation in and the Mean Ordinal Value of Individual Discussions with the Instructor in Lecture and P.S.I. Sections | 29 |
| IX. | Student Perceptions of Workload | 33 |
| X. | A Comparison of Per Student Costs for Lecture Section vs. a P.S.I. Section | 34 |

# I. Introduction

## An Overview

The Personalized System of Instruction (P.S.I.), known also as the Keller Plan in honor of its originator Dr. Fred Keller, Professor Emeritus, Columbia University, represents an alternative method of instruction to both conventional lecturing and programmed learning. Various features of this method have made it appealing to a growing number of disciplines and schools.[1] The usefulness of this method in terms of where it works best and where it may not work at all in comparison with alternative methods will be evaluated only after a large number of classroom experiments have been run with it.

In economics few evaluations of this technique have been reported in the literature. Those of which I am aware have been conducted within the environment of a large university and have evaluated the application of the technique to an introductory economics course.[2] Since the transferability of experimental results across courses and across types of institutions is not

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1. In June, 1972 the Personalized System of Instruction Newsletter published by the Department of Psychology at Georgetown University reported that it had been informed of some 190 courses being offered under the Keller Plan format for such diverse fields as English, sociology and mathematics.

2. One experiment was conducted at Vanderbilt by Ben Bolch, Rendigs Fels and Robert Uhler and the other by Elizabeth Allison at Harvard. The results of the former experiment were reported at the 1972 meetings of the American Economics Association.

at all obvious, the purpose of this paper is to report on an experiment which is differentiated from previous studies in two ways: (1) the P.S.I. technique was employed on a microeconomics course in which a one semester introductory course was a prerequisite and (2) the experiment was conducted within the environment of a small liberal arts college (Williams).

The Nature of the Personalized System of Instruction

The P.S.I. attempts to aid the student in mastering the course material by allowing him to proceed at his own pace (subject to some constraints discussed below) and by providing him with frequent and rapid feedback as to whether or not he is in fact mastering the material. Structurally, a typical P.S.I. course is divided up in 16 or so units. Each unit contains: (1) an introduction, which relates this unit to previous units and to the body of the course in general, (2) a set of objectives in which the student is informed in as precise terms as possible exactly what the educational objectives of that unit are, (3) a set of procedures by which these objectives may be satisfied and (4) a set of sample problems or discussion questions that the student can use to test his understanding of the material before taking a test.

Although P.S.I. courses hold normal classroom hours, no lectures are delivered during these hours.[1] Instead the time

1. Special lectures are recommended by the originators of P.S.I. to serve as motivational devices. These lectures, which would be open only to students who have passed a particular

is used for discussion, explanation and test taking. The elimination of lectures allows the introduction of two degrees of flexibility not generally shared by lecture courses. In the first place it permits the student to proceed through the course material at his own pace instead of forcing him to proceed at the predetermined pace of the lectures. This flexibility should be interpreted carefully, however. When the course has a fixed deadline for completion, as did the experiment described here, the value of self-pacing lies not in allowing the student more time, for it does not do that, but rather in allowing the student greater flexibility in allocating the time he or she spends on the P.S.I. course over the course of the semester.

The second degree of flexibility offered by the P.S.I. is that instead of spending time in the classroom lecturing the professor is available during these hours for individual consultation and discussion with students. This contact with the student is personal in the sense that the discussion with the student can be oriented to the specific problems and specific interests of that student. It is this kind of one-on-one communication between professor and student which accounts for the "Personalized" in P.S.I. One professor could not possibly grade all the tests, which provide the main flow of feedback to the

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unit within a stipulated period of time, would presumably be interesting applications of what was learned in the previous units. The material from these lectures would not be subject to testing. These special lectures were not used in this experiment.

student, and carry on this kind of tutorial relationship with the students in courses larger than 5-10 students without the formation of large queues of students waiting for access to the professor. To alleviate this problem the faculty member is assisted by undergraduate proctors whose job it is to grade exams and provide answers to the easier questions. Experience has shown that one proctor for each ten students provides a reasonable basis for adequate feedback and discussion.

The student proceeds through the course unit by unit. He passes on to the next unit only when he has demonstrated mastery of the previous unit. Mastery is demonstrated by the achievement of a perfect or near perfect score on a unit test. The tests are commonly made up of short answer questions which can be quickly graded by one of the proctors in front of the student. In the case of missed questions the student is sent back to master a specific body of material. When he feels he has mastered the material, he can take a different test on the same material.

The grading of a P.S.I. course differs from the conventional course in a couple of ways. In the first place failures on unit tests have no direct effect on course grade. They merely slow the student down. The second aspect of P.S.I. grading is that it involves a form of contract between the professor and the student. As the semester starts both the student and the professor know exactly what has to be done for an A+, an A, a B and so forth. This can be contrasted with the conventional

practice of curve grading in which some distribution of grades is superimposed over a class ranking. The former grading system tends to be based on more absolute standards or mastery of material while the latter tends to be more relative.

There are other differences between P.S.I. and the traditional lecture method as well. In P.S.I. knowledge is transmitted primarily via the written word as contrasted with the mainly verbal transmission in a lecture course. Since reading and assimilating material do not draw upon the same skills as listening and note taking, the two approaches could conceptually lead to different distributions of learning among students.

## II. The Nature of the Experiment

### Background

The types of educational objectives which characterize an economics education range in complexity from the memorization of simple definitions and facts to the acquisition by the student of the ability to reason analytically in an unstructured environment. While the P.S.I. seems perfectly appropriate to satisfy the simpler educational objectives it is less clear that the method is appropriate for achieving the more complex objectives. The questions used to test the depth of understanding on these more complex and unstructured applications are by their very nature essay questions which are not quickly graded and which

are certainly much less amenable to proctor grading than more objective tests. These characteristics make it difficult to incorporate essay questions into the unit tests. Since the unit tests are the main means of reinforcing what the student learns, this raises the question as to whether the use of the P.S.I. might preclude this important form of learning.[1]

The P.S.I. course designed for this experiment attempted to stimulate this type of learning by taking two steps. First of all the discussion questions in the units which are designed to guide the student in his mastery of the material included unstructured essay questions. Secondly, it was emphasized that although this kind of question would not appear on the P.S.I. unit tests it would appear on the final. The plan was that the discussion questions would focus the student's thinking on this type of learning and the promise that essay questions would appear on the final examination would drive the student to the professor to see how one might go about dealing with these kinds of questions. From there the professor could capitalize on the opportunity for a one-to-one relationship provided by the P.S.I. to think through these problems with the student.

So much for the objectives of the course, perceived *a priori* limitations of P.S.I. and modifications to attempt to

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1. A more serious concern would be that the faculty member's behavior would be altered as well. When the faculty member discovered what kinds of learning were best accomplished under the P.S.I. he may well be tempted to eliminate all other forms of learning to improve the performance of his students.

deal with them. The experiment was designed to see how this method of teaching could accomplish these goals. The rest of the paper summarizes the details of the experiment and the results which were derived from it.

An Overview of the Experiment

A total of 92 students were allocated to three sections of microeconomics. Two of the sections were taught in a conventional lecture format and the final section was taught in the P.S.I. format. All three sections met for two one and one-half hour periods a week. Each student was exposed to the same body of material. The course was based on a conventional text which all sections used. The P.S.I. section students had the text supplemented by written handouts which consisted of the kind of elaboration and/or clarification that would ordinarily occur in a lecture.

All students were administered a common final examination. The experiment was designed to compare the lecture sections with the P.S.I. section both on the input side (e.g., student time, faculty time, material cost) and output side (e.g., final exam scores and student perceptions of the value of the educational experience). On the output side the empirical testing was based upon two instruments -- the final examination and the course evaluation. These instruments are so central to this evaluation that they are separately described below, but first their role in the experiment will be discussed.

The first analysis was performed on the final examination scores. The technique of regression analysis was used to isolate insofar as possible the unique effects of the teaching method on final exam score. Specifically the answers for two questions were sought:

(1) Were there observable differences between the students in the P.S.I. section and the students in the lecture sections in their performance on the final examination after controlling for other various measurable influencing factors?

(2) Is this differential, if any, uniform across students of different abilities or is the performance differential higher for students with a record of successful past performance in economics? or higher for students with a somewhat lower level of performance in the past?

The second unit of analysis is the course evaluation form. Since these are filled out anonymously, it is not possible to link the responses to a particular student. Therefore, the analysis of these forms is restricted to comparisons of mean scores across sections.

Two constraints were imposed on the experimental design which made the analysis somewhat more difficult than would have been the case if it were a completely controlled experiment. Manpower considerations dictated that no professor could teach more than one section. This made the isolation of the technique differences more difficult because they were intertwined with differences in teaching ability among the faculty members. The method of controlling for faculty teaching differences is discussed below.

The second constraint resulted from the desire to be fair to the students. Fairness in this case translated into freedom of choice. Students were notified in advance which section was to be the P.S.I. section and within limits were allowed to choose the type of instruction they would receive.[1] The impact of this on the analysis was that it was not possible to isolate differences in attitudes before the course from attitudes acquired during the course of instruction.

The Final Examination

The final examination was worth a total of 120 points. It consisted of three parts all equally weighted. The student was asked to answer all questions. The first part consisted of 8 short answer questions in which the students were given eight false statements and asked to explain why they were false. The second part consisted of 4 questions which represented a combination of 2 numerical problems and 2 ten minute discussion questions. The final part consisted of 2 twenty minute questions, the first of which was a complex application of general equilibrium analysis and the last question was a multipart question in which the student was faced with successively more difficult questions concerning the impact of alternative taxes on

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1. An upper limit of 32 students was imposed on the P.S.I. section. This limit forced about four students who pronounced a preference for the P.S.I. section to attend a lecture session instead. In addition not all students received their first choice because of course conflicts, etc.

consumption. The examination was, therefore, composed of a variety of question types and because of this it affords the opportunity to draw inferences about the robustness of student ranking with respect to the structure of the testing instrument.

The examination was put together from a pool of questions submitted by the three faculty members. To avoid possible biases in grading each faculty member graded one part of the examination for all 92 students without knowing which student's paper was being graded. Before the grading commenced scales were drawn up for each of the three parts to insure that an A answer on Part I would be worth roughly the same amount of points as an A on Part II and so forth.

The Course Evaluation

The course evaluation form used in this report is the standard instrument administered to almost all courses at Williams College. (A copy of this form is attached as Appendix A.) On this form students are asked to rate the professor on various traits usually associated with good teaching and the course in terms of its educational value. These ratings are based on an ordinal scale from one to seven with a score of seven carrying a connotation of outstanding. In assigning these ratings the students are asked to compare the professor and course being rated with other faculty members and courses they have had at Williams.

Potential Biases in Interpreting the Results

There are a number of dangers in using the results in this experiment as a basis for drawing conclusions about the effectiveness of the P.S.I. for other populations. The main potential bias in using this experiment to forecast student performance in repeated application of this P.S.I. course over time would be experimenter bias.[1] Past experiments with humans have indicated that the experimenter is not a neutral part of the experiment. His motivation and expectation can influence the performance of the students. If, as is natural, with repeated application this motivation of the faculty member diminishes, so may the performance of the students. While there is every reason to capitalize on this bias in the short run as a means of increasing learning, the performance differentials which are due solely to this experimenter bias may well disappear in the long run.

A second possible bias, which acts in the opposite direction, in using the results of this experiment for forecasting the results of repeated application stems from the fact that the materials for this course were used for the first time in this experiment. Certainly as experience is gained in their use significant improvements in them can be achieved. This bias would work to increase the performance of the P.S.I. students vis a vis their colleagues in the lecture sections.

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1. A good short description of types of experimenter bias can be found in Leonard P. Ullman and Leonard Krasner A Psychological Approach to Abnormal Behavior (Englewood Cliffs: Prentice-Hall, Inc., 1969), pp. 90-91.

Other biases might exist if one were to attempt to extrapolate the results of this experiment to other populations. The success or failure of a particular P.S.I. course is dependent upon the quality of the materials, the quality of the tutors and the type of student enrolled in the course. These will vary widely among courses and schools and different combinations of these factors will yield different degrees of success or failure.

Profile of the Sample

Table I presents information which is useful for two purposes.[1] It portrays the means of some of the input characteristics of the students which gives a feel for the composition of the sections. Secondly, it permits the testing of the hypothesis that allowing students to select their method of teaching would lead to quite different student composition in the two types of sections. If, for example, the students who had experienced the most success in economics in the past felt that the P.S.I. section offered the best opportunity for them, while the students who had experienced somewhat lower success felt that the lecture method was the best for them, the mean economics grade point average should be significantly higher for the P.S.I. section.

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1. Out of the 92 students who took the course only 80 had complete background records which were usable for the analysis. Of these excluded 12 records 6 were women exchange students and 4 were foreign students. Both groups had either not taken the college board tests or had not had their scores recorded on their Williams record. The remaining two observations were dropped because the final examination which they took was not directly comparable to the exam taken by all other students.

TABLE I

Mean Values of Selected Student Characteristics for Lecture and P.S.I. Sections

| Variable | P.S.I. Section | Lecture Sections | Difference of Means t-ratio |
|---|---|---|---|
| Mean Economics Grade[1] Point Average | 8.34 | 7.82 | 1.290 |
| Mean S.A.T. - Math[2] | 680.5 | 682.8 | 0.165 |
| Mean S.A.T. - Verbal[2] | 635.9 | 625.4 | 0.632 |
| Mean Age | 19.2 | 19.2 | 0.000 |

[1]This grade point average is based on a 12 point scale. An 8 is a B and a 7 is a B-.

[2]These are the scores received on the Scholastic Aptitude Test of the College Entrance Examination Board.

To test for a difference in student composition between the two types of sections resulting from allowing students to select their own method of instruction, a series of difference of means tests was run on the four variables given in Table I and the resulting t ratios are given.[1] It is not possible to reject the hypothesis at the 90% level of confidence that these two samples were drawn randomly from the same parent population. In other words the differences of means for each of the three variables are well within the range which can be attributed to

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1. The description of the t-test used can be found in Alexander M. Mood and Franklin A. Graybill, Introduction to the Theory of Statistics, Second edition (New York: McGraw Hill Book Company, Inc., 1963), p. 306.

sampling error. Statistically the hypothesis that the two types of sections are the same in terms of these four student characteristics cannot be rejected. Apparently no clear advantage to either method was perceived uniformly by a single type of student as defined by the four variables in Table I.[1]

## III. An Analysis of the Output Measures

The often cited advantages of using a P.S.I. method are: (1) enhanced student performance, (2) better retention of material for longer periods of time, (3) the students are enthusiastic about taking P.S.I. courses and (4) the students are allowed a much greater flexibility in allocating their study time. In this section the first, third and fourth of these potential advantages will be examined within the context of the above described experiment. Retention will be examined in a follow up study in a couple of years.

### Student Performance

The evaluation of student performance, based on the testing instrument described above, is concerned with three questions: (1) does the P.S.I. lead to superior performance? (2)

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1. These results are in no way conclusive because all students did not have completely free access to either section because of course conflicts and the ceiling imposed on the P.S.I. section. One can only speculate on how completely free access would have changed the values in Table I.

what group of students seemed to benefit most from the P.S.I. -- students entering the course with high grade point averages? students entering the course with low grade point averages? neither? both benefit equally? (3) to what extent are these results sensitive to the form of the testing instrument?

The objective was to establish whether performance differentials exist after controlling for differences in student abilities. The method of analysis was to develop a linear model to predict the student's performance on the final examination based on his characteristics on entry into the course.[1] This model can be represented symbolically as:

$$(1)\quad T_i = \quad + B_1X_1 + B_2X_2 + \ldots + B_kX_k + e_i$$

where $T_i$ is the final examination score for the ith student, and the B's are the parameters to be estimated, and the X's are student characteristics such as sex, past economics grade point average, scores on the math and verbal portions of the Scholastic Aptitude Test, age, etc. and the teaching experience of the student's professor. The $e_i$ is a random disturbance term which captures all of the other influences on student performance. For the hypotheses tests which follow this unobserved disturbance term is assumed to be normally distributed.

For this model there are two hypotheses to be tested. The first hypothesis is that the introduction of the P.S.I.

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1. The linear specification was compared to other functional forms which could be transformed into linear forms. The linear specification had the highest explanatory power of any functional form in this class.

TABLE II

Estimates of the Parameters of a Linear Model to Predict Final Examination Scores
( N = 79  $R^2$ = .416 )

| Variable | Estimated Coefficient | t value |
|---|---|---|
| Economics grade point average | 3.136 | 3.478** |
| S.A.T. - Math | 0.064 | 2.796** |
| S.A.T. - Verbal | -0.003 | -0.156 |
| Early Final[1] (1=early final; 0=regular final) | -3.692 | -0.693 |
| Age of student (in years) | -1.659 | -1.055 |
| Had math course at Williams (1=yes; 0=no) | -0.161 | -0.058 |
| Sex (1=female; 0=male) | -3.602 | -1.034 |
| Teaching experience of professor[2] (in years) | 2.672 | 2.673** |
| P.S.I. (1=P.S.I.; 0=Lecture) | -2.743 | -0.197 |
| P.S.I.X Economics grade point average[3] | 0.686 | 0.392 |

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[1]The final was given a month early to all P.S.I. students who had finished the course and who wished to take the early final.

[2]This variable, used as a means for controlling for differences in teaching experience across sections, was defined simply as the number of years teaching experience prior to the start of the experiment. That teaching experience is important and needs to be controlled for was suggested strongly by the results in Richard Attiyeh and Keith Lumsden, "Some Modern Myths in Teaching Economics: The U.K. Experience," The American Economic Review, LXII (May, 1972), 429-433.

[3]This interaction variable is defined as the economics grade point average for P.S.I. students and 0 for all other students.

**Statistically significant at the 99% level of confidence.

method made no difference in the final examination scores of equally experienced faculty members. The verification of this hypothesis translates into a test that the coefficients on the last two variables in Table II are simultaneously zero.[1] With an F value of 0.45 for the test statistic it is impossible to reject the hypothesis at any conventional level of confidence. The introduction of the P.S.I. method made no statistically significant difference in final examination scores.

The second hypothesis is that the P.S.I. method has no discernable differential impact among students who have experienced varying degrees of success in economics in the past. The verification of this hypothesis translates into a test that the coefficient for the interaction variable (the last variable in Table II) is zero. The results of this conventional t-test are presented in Table II. Once again it is not possible to reject the hypothesis for any conventional level of confidence.

Although the differences were not statistically significant, they were present. The interesting fact is that the sign of the

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1. The appropriate test is given in J. Kmenta, Elements of Econometrics (New York: The Macmillan Co., 1971), p. 371.

TABLE III

Estimated Percentage Improvement in Final Examination Score Resulting from P.S.I. for Students of Differing Abilities

| Past Economics Performance | Percentage Improvement |
|---|---|
| Highest Quartile | 6.5% |
| High Middle Quartile | 5.4% |
| Low Middle Quartile | 4.2% |
| Lowest Quartile | 2.3% |

coefficient on the interaction term was positive. This means that the number of points improvement in expected final exam grade from switching to a P.S.I. section will be higher for students with high economics grade point averages than for students with lower grade point averages. Using the coefficients presented in Table II it is possible to compute the percentage improvements for students of differing abilities. This is a puzzling and discouraging result because one hope for the P.S.I. would have been that it would have been a boon for the less able student.[1] Because the course is based on mastery, one would expect a compacting of the final grade distribution for the P.S.I.

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1. It should be noted that more encouraging results were achieved using TIPS. See Allen C. Kelley, "TIPS and Technical Change in Classroom Instruction," American Economic Review, LXII (May, 1972), p. 425.

section.[1]

Having examined the results for the final examination in its entirety we now turn to the question of how sensitive these results are to the form of the testing instrument. The underlying issue which makes this an important question is the frequently voiced suspicion that the P.S.I. method is severely hampered by the fact that the unit tests, in order to provide rapid and frequent feedback and be amenable to proctor grading have to consist primarily of short, objective questions. The argument is that if longer, more subjective questions cannot appear on the unit tests then the learning processes which are best evaluated by these methods will never take place. The student, indeed, is systematically steered away from these forms of learning by limiting positive reinforcement to the more objectively evaluated skills. Therefore, the argument continues, the P.S.I. is limited to teaching concepts which are amenable to evaluation by objective, short answer questions which represents only a (small?) part of the desired transfer of knowledge between faculty member and student.

In order to refute or substantiate these suspicions

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1. The variance of final examination grades for the P.S.I. section was smaller than the variance in the final grades in the two lecture sections combined and smaller than the variance in each lecture section separately; however these differences were not statistically significant. The variance test can be found in A.M. Mood and F.A. Graybill, Introduction to the Theory of Statistics, 2nd edition (New York: McGraw Hill Book Company, Inc., 1963), pp. 307-308.

empirically it was necessary to translate them into hypothesis tests. As a first step the score on the final examination was disaggregated into four sub-scores. The first three scores were the mutually exclusive scores achieved on each of the three parts of the examination. The main element of difference among these parts was the complexity of the questions and the time allocated to doing them. The fourth subscore was the total number of points accumulated by the student on the three questions which were less oriented toward problem solving and more oriented toward a discussion of the issues. These questions were in an essay format and clearly more subjective. These three questions required the student: (1) to discuss the underlying value judgements in the economic concept of efficiency, (2) to explain and critique the position of the New Left economists on marginal productivity theory and the income distribution and (3) to trace the general equilibrium effects of a particular technological change on various sectors of a three sector economy.

For each of these four component parts of the final examination the model was reestimated with the dependent variable being the score on that portion of the test and the independent variables remaining as they were described in Table II. Then the two hypotheses described above were tested on these four new sets of data. The test that the P.S.I. method did not make any difference could not be rejected for any conventional level of confidence.[1] Similarly, the test that improvements in final

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1. The F values were respectively -- .401, .445, .054 and .106.

examination scores attributable to the P.S.I. technique were the same for students with differing past performance records in economics could not be rejected for any conventional level of confidence.[1]

While these findings are consistent with the more general hypothesis that the P.S.I. method is not severely hampered by the necessity for the unit tests to be of the short, objective variety, it is important to report the measured differences so that future experiments can determine whether or not they persist under repeated experimentation.

TABLE IV

Estimated Percentage Improvement Attributable to the P.S.I. Method by Students of Differing Abilities on Component Parts of the Final Exam

| | Components of the Examination | | | |
|---|---|---|---|---|
| Past Performance in Economics | Short Answer | Medium Answer | Long Answer | Essay |
| Highest Quartile | 5.6% | 10.8% | 1.1% | 5.3% |
| Upper Middle Quartile | 5.9% | 8.4% | -0.4% | 3.3% |
| Lower Middle Quartile | 6.1% | 5.8% | -2.5% | 0.5% |
| Lowest Quartile | 6.5% | 2.0% | -4.7% | -4.2% |

The information in Table IV points out that the distribution of educational benefits was affected by the type of question

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1. The t-values were respectively -- .050, .488, .262 and .420.

asked. On the short answer questions, which were the ones most like the format of questions found on the unit tests, the students with the poorest past performance record were benefitted marginally more than students with superior past performance records. This effect, however, was offset by the rest of the examination. As the examination questions become longer, more complex and less structured the poorer students did relatively less well. For the essay questions and the long answer questions apparently the poorer student would have been better off in a lecture section.

Although ex post rationalizations of these results must be regarded as extremely tentative, in retrospect one explanation seems quite plausible. Mastering the material took a greater input of time on the part of the poorer students. As a result they had to keep up a constant pace in order to finish the course on time. They were preoccupied with passing the unit tests and virtually ignored the discussion questions on the units. Therefore they were not able to develop their powers of generalization and analytical reasoning in an unstructured environment to the same extent as their colleagues with similar past performance records who were taught by the lecture method.

The students with the best past performance records, on the other hand, could master the material in less time so they had more time to pursue these more difficult educational objectives. They discussed the essay questions with me and with each other and in the process sharpened their generalization skills.

In short they were able to capitalize on the format of the P.S.I. to accomplish a broad range of educational objectives whereas the slower student was not. If these conjectures are valid, they may weaken the case for P.S.I. courses taught within the regular semester and strengthen the case for P.S.I. courses taught without deadlines for completion.

Student Perceptions of Their Educational Experience

Performance on final examinations is not the only criterion by which the educational process can be or should be judged. Other significant facets include the degree to which the course taught the student to pursue the subject matter on his own, the degree to which the course taught the student new ways to understand and evaluate problems and the degree to which the course provides a basis for discussion outside the classroom. The course evaluation instrument used at Williams, which was described above, provides one considerably less than perfect, but nonetheless useful, vehicle for assessing these other dimensions.

Table V summarizes the information from the course oriented questions in this evaluation form. The table gives the

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1. Inevitably questions will arise about the evaluation instrument and whether or not student perceptions are accurate and if they are accurate, whether they are important. My own experience with the evaluations at Williams is that the students are very perceptive and I tend to find them informative and useful. In my opinion the possibility of experimenter bias is a potentially more damaging criticism.

TABLE V

Student Perceptions of Their Educational Experience in the P.S.I. and Lecture Sections

| Course Characteristic | P.S.I.[1] Mean | Lecture[1] Mean | Difference of Means t-ratio |
|---|---|---|---|
| Taught me to pursue subject on my own | 5.59 | 4.36 | 2.93** |
| Stimulated me to discuss the subject in general conversation | 5.07 | 3.81 | 3.69** |
| Increased my appreciation of the subject | 5.79 | 4.33 | 4.12** |
| Course has taught me new ways to understand and evaluate problems | 6.00 | 5.45 | 1.70* |
| Overall rating of the Educational Value | 6.30 | 4.96 | 4.35** |

[1]These are based on an ordinal scale from one to seven with seven connoting outstanding.

**Significant at the 95% level of confidence.

*Significant at the 90% level of confidence.

mean for each method of teaching and the value of the t-ratio which is the statistic used to test whether these means are different in a statistical sense. The P.S.I. section received a higher rating on all dimensions. In four of the five dimensions the P.S.I. mean was significantly higher using a 95% level of confidence and in the remaining dimension the P.S.I. mean was significantly higher using a 90% level of confidence.

As one thinks about these questions keeping in mind the

method used in P.S.I. the statistical superiority of the P.S.I. may be surprising. For example, one hypothesis could have been that one of the costs of the highly individualistic approach embodied in the P.S.I. would be a drop in the interaction among students since the students could conceivably be proceeding at quite different paces. As shown in the second row in Table V the students in the P.S.I. section perceived themselves as being more stimulated to discuss microeconomics out of class than did their colleagues in the lecture sections.

In the final question the students were asked to subjectively rate the educational value of the course. The P.S.I. sections perceived the course to be of greater educational value than did their colleagues. The course evaluation form also asks the students to describe their degree of motivation for the course by categorizing it as very high, high, moderate or low. The responses to this question by method of teaching are given as Table VI. About 92% of the students in the P.S.I. section

TABLE VI

Student Perceptions of Their Degree of Motivation in the P.S.I. and Lecture Sections

| My motivation in this course can best be described as: | P.S.I. | Lecture |
|---|---|---|
| Very high | 37.0 | 13.5 |
| High | 55.6 | 42.3 |
| Moderate | 7.4 | 30.8 |
| Low | 0.0 | 13.4 |

proclaimed themselves either highly or very highly motivated while only 56% of the lecture sections recorded a similar degree of motivation. While it cannot be determined, given the way the question was asked, how much of this difference in motivation was already present at the beginning of the semester, the differences are striking. The students in the P.S.I. section perceived themselves to be on the whole much more motivated than did their colleagues in the lecture sections.

The final piece of information contained in the course evaluation was a question which asked the students in retrospect to choose the method of teaching which they would believe to be the best for conducting the microeconomic theory course. The tabulated responses are presented below.

TABLE VII

Percentage Responses on Desired Teaching Technique for P.S.I. and Lecture Sections

| This course would be best conducted as: | P.S.I. | Lecture |
|---|---|---|
| Formal Lecture | 0.0 | 44.0 |
| Informal lecture with discussion | 3.7 | 32.0 |
| P.S.I. | 96.3 | 24.0 |
| | 100.0 | 100.0 |

Of course in a question of this sort there is probably always a tendency to prefer the method chosen, but once again the differences are striking. Only one person who took the P.S.I. would have preferred a variant of the lecture method, but almost one

quarter of those in the lecture sections felt, in retrospect, that the course would be best taught by the P.S.I. method.

Timing Flexibility[1]

One of the desirable aspects of a P.S.I. method is that it provides any student who can master the material at a rate faster than the pace taken by the traditional lecture method with the opportunity to allocate his study time in a manner consistent with his individual program. The relevant question, however, is whether this option is used to any extent by the students. If not, the timing flexibility is a more apparent than real advantage.

The records kept on when each student passed each unit indicate considerable diversity among students in the time phasing of mastering the course material. Nine of the thirty-two persons finished at least one month early. Four more finished three weeks early. Two did not complete all the units, but one of these was bedridden with mononucleosis during a good share of the semester.

An analysis of the persons who finished at least a month early reveals, not surprisingly, that they were all B+ or above students in economics in the past. Not all such students,

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1. This dimension of the P.S.I. experience can either be considered an output, desirable in its own right, or as an input, desirable only to the extent that it leads to superior performance. Its inclusion in this report as an output reflects the author's judgement on the relative merits of these two positions.

however, chose this rapid pace. The student who had completed the fewest number of units (5) when the first person to complete the course had finished was a straight A student in economics. This once again reinforces the point that the self-pacing feature of P.S.I. is a feature which appears to benefit mostly the students who have already demonstrated a superior capability in economics.

Since eight of the early finishers took an early final, it is possible to statistically test the proposition that there was no difference in performance between those who took the early exam and those who took the regular final. Table II reveals that on average the early finishers did not do as well as those who took the later examination, but the differences were not statistically significant. An examination of the separate results for each of the component parts of the exam reveals that the sign of the early final variable was positive on the short answer portion of the examination and negative for the rest of the exam. Since the early finishers used less time to complete the course, this result is consistent with the above conjecture that students who are the most pressed for time sacrifice the more complicated educational objectives in favor of mastering the more objective, less general concepts.

Student-Faculty Interaction

Another of the alleged benefits of the P.S.I. method is that it fosters a beneficial individualized contact between the

student and the professor. It fosters this kind of contact by (1) releasing faculty time from lecturing and making that time available to students and (2) by meeting with the students in the classroom where any reluctance to visit the professor in his office can be circumvented. The course evaluation form allows us to test whether this benefit is empirically supported by this experiment. One of the questions on the evaluation instrument asked the student to rate the value of individual discussions with the instructor on a seven point scale as to how much they had learned from these discussions. Those who had not had such discussions were to check "doesn't apply." This question allows us to check both the degree of faculty-student interaction and the perceived value of this interaction to the learning experience. The results are presented in the Table below.

TABLE VIII

A Comparison of the Degree of Participation in and the Mean Ordinal Value of Individual Discussions with the Instructor in Lecture and P.S.I. Sections

| | P.S.I. | Lecture |
|---|---|---|
| Percentage Reporting Individual Discussions | 74.1 | 47.4 |
| Mean Ordinal Contribution to Learning (on a Seven Point Scale) | 5.75 | 3.74 |

Both differences are significant at the 99% level of confidence.[1]

1. The test to compare the percentages can be found in Taro Yamane, Statistics, An Introductory Analysis (New York: Harper & Row, Publishers, 1964), pp. 552-3.

It would appear that at least for this experiment the P.S.I. method does foster an individualized student-faculty relationship and that this relationship is perceived by the students as being somewhat more educational than the relationship fostered by the lecture method.[1]

## IV. An Analysis of the Inputs

The relationship between inputs and outputs in the P.S.I. method is not the same as in a regular lecture course. Most of the input differences would be reflected in differences in the monetary cost of running the course, but two would not -- faculty time and student time. Faculty time is not fully reflected in the cost because the instructor is paid in terms of the number of sections taught and his salary is, in the short run at least, not systematically related to the amount of time that he or she puts in preparing for that class. Thus two teaching techniques may appear to cost the same when in fact one, by its very nature, takes much more time to prepare. For this reason faculty time will be considered separately.

Similarly student time is not part of the monetary cost. Since the P.S.I. method requires the student to take a more active role in his education, he or she may well have to work harder, which may affect his or her other courses. Therefore,

1. Since this result could be sensitive to the faculty members involved, the values for each of the two lecture sections were examined separately. The differences are also statistically significant between the P.S.I. section and each of the other two sections separately.

the demands on student time made by this P.S.I. course and its impact on other courses will also be examined separately below.

Faculty Time. Of interest to faculty members is the question, "how much time does it take to prepare a P.S.I. course as compared to a regular lecture course?" The first difference between these two techniques is that for P.S.I. sections the workload tends to be redistributed more toward the beginning of the course. Generally it is recommended that at least one-half of the units and unit tests be completed before the class starts.

The comparison of the total amounts of time involved depends on the circumstances.[1] After running this experiment it is clear that the total time devoted to setting up a course of this type was on the order of one and one-half times as much as is devoted to setting up a lecture course the first time one teaches it. For instructors who have been teaching the same course for some years and who intend to teach it again with only minor modifications the initial additional time required to switch to a P.S.I. method would be much greater.

The main dimension of the P.S.I. method which leads to this differential is the necessity for writing up to four different tests for each unit (to allow for multiple failures). Writing this number of test questions which are comprehensive,

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1. The time estimates in this section are based not on a meticulous time budget, but rather on some ex post, impressionistic estimates. They are rough and approximate.

fair and which satisfy the educational objectives is a difficult proposition.

However, once the materials have been developed the time devoted to the P.S.I. method would appear to be only minimally higher as long as the basic structure of the course remained the same. The reason for its being minimally higher is that modifications of the course are slightly more difficult in a P.S.I. course since they have to be carefully rewritten for the student whereas in a lecture course it is possible to jot the change down on the lecture notes and deliver the embellishment extemporaneously. In short once the initial time has been spent in setting up the P.S.I. course the first time the faculty time requirements appear to be only marginally higher for an instructor repeating a course regardless of whether he is repeating a P.S.I. course or a lecture course.

Student Time. The course evaluation form provides some information on student perceptions of the workload in a P.S.I. course as compared to the perceptions of students in the lecture sections. As reflected in Table IX it is clear that more of the P.S.I. students perceived their workload as being heavier than average than did the students in the lecture sections.

Although the students seemed to find this extra work educationally well spent, as discussed above, the question remains as to whether or not this increased workload would lower student performance in other courses. To answer this question the grade point average for the other courses taken during the

TABLE IX

Student Perceptions of Workload (Percentage)

| The workload for this course in relation to other Williams Courses was: | P.S.I. | Lecture |
|---|---|---|
| Much lighter | 0.0 | 2.0 |
| Lighter | 10.7 | 11.5 |
| About the same | 21.4 | 57.7 |
| Heavier | 64.3 | 25.0 |
| Much Heavier | 3.6 | 3.8 |
| Total | 100.0 | 100.0 |

same semester as the microeconomics class was computed for every student in the sample. Then for the total population this other course grade point average was regressed against (1) the cumulative grade point average at the beginning of the semester and (2) a binary variable indicating whether or not the student was a member of a P.S.I. section. The results of this estimation were:[1]

$$O_i = 1.83 + \underset{(.106)}{.787}\, C_i + \underset{(.301)}{.097}\, R_i \qquad R^2 = .435$$

where $O_i$ = the predicted other course grade point average,

$C_i$ = the cumulative grade point average for the ith student at the beginning of the semester,

$R_i$ = 1 if the student was a member of a P.S.I. section, 0 otherwise.

The P.S.I. students did better in their other courses

1. The numbers in parentheses are the standard errors of the coefficients.

than would have been expected purely on their grade point average, but the difference is not statistically significant. It would certainly appear that the P.S.I. method does not detract from the other courses.

Costs

The main elements of cost are the material cost and labor costs. The labor costs will differ according to who the instructor is, his rank and so forth. The following rough estimates of per student costs are based on the assumption that the lecture section and the P.S.I. section are being taught by junior assistant professors earning $12,000 a year for teaching five sections.

TABLE X

A Comparison of Per Student Costs for Lecture Section vs. a P.S.I. Section

| | P.S.I. | Lecture |
|---|---|---|
| Typing of Materials | $ 2.17 | $ .25 |
| Duplication of materials | 2.54 | .15 |
| Faculty Pay | 80.00 | 80.00 |
| Tutor Pay | 12.00 | --- |
| | $96.71 | $80.40 |

These figures suggest that a P.S.I. course structured like the one described in this paper costs about 20% more per student than the conventional lecture course largely due to the cost of

the tutors. This could be modified, of course, by finding nonmonetary ways to compensate the tutors (e.g., by offering them some sort of course credit for tutoring rather than money).

Since the typing costs and faculty costs are fixed and the remaining categories are characterized by constant marginal cost, it follows that the average cost per student of teaching this course by the P.S.I. method declines asymptotically to $14.54 per student for a class containing an infinite number of students. Although teaching a section by the P.S.I. is never cheaper than a lecture section of equivalent size taught by one faculty member because the fixed costs are larger, it does offer a kind of middle of the road alternative to the choice between one very large lecture section and more than one small section. It can fill this role if it can maintain the kinds of performance standards of the small sections while using only one faculty member in conjunction with tutors. It should be noted, however, that this kind of approach would make the instructor much less accessible to the average student in the classroom.[1] The monetary savings would be balanced by a reduction in the accessibility of the instructor.

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1. A logical criticism of this point would be "if performance is not affected why should you care about accessibility? After all, isn't it only an input?" My concern with this logic arises from my firm belief that not all educational outputs are measured. A case in point would be the discussions with students about tangential points which interest the students. The value of this kind of discussion is to draw the student into thinking about economic problems more deeply than he had before by taking advantage of his interest in this subject. This kind of interchange is motivating and valuable but rarely measured by a final exam.

## V. Summary and Conclusions

### Summary

1. There was no statistically significant difference between the performance of the P.S.I. students and the lecture students on either the final examination as a whole or on any of its component parts after controlling for student characteristics and the teaching experience of their professors.

2. The distribution of educational benefits among students with differing past performance records in economics was not uniform among component parts of the examination, but these differences were not statistically significant either. The students with the poorest past performance records scored better than their colleagues in the lecture sections with equivalent records on the short answer objective questions, but less well on the longer, more subjective questions.

3. The students in the P.S.I. section perceived themselves to be deriving significantly more educational value from the course than did their colleagues in the lecture sections.

4. The greatest use of the flexibility inherent in the self-pacing feature of the P.S.I. was made by the students who had demonstrated superior performance in economics in the past. The slower students worked at a steady pace.

5. The P.S.I. method seems to enhance the value of

individual discussions between instructor and student both by making this learning experience more available to students and by making it a more valuable part of the learning process.

6. The faculty time required to develop this P.S.I. course from scratch was roughly one and one-half times greater than the time required to draw up a lecture course from scratch.

7. Once established the faculty time requirements for repeating a P.S.I. course appear to be only slightly higher than the time requirements for repeating a lecture course.

8. A much higher percentage of the students in the P.S.I. section viewed themselves as working harder than average on this course than did the students in the lecture sections.

9. In spite of this increased workload the P.S.I. students did better on their other courses after controlling for differences in student abilities, but this better performance was not statistically significant.

10. For the way this experiment was conducted the monetary cost of administering the course was about 20% higher per student for the P.S.I. method than for the lecture method.

Conclusions

In conclusion neither the most damaging arguments against the P.S.I. system nor the most compelling arguments for it were upheld by this experiment. It does not appear to be inherently

biased toward the accomplishment of simple educational objectives. Neither the areas on which it achieved better results than the lecture method nor the areas on which it fell behind the results for the lecture method were characterized by differences large enough to be statistically significant. It does not appear to provide a boon for the below average student as long as the course must be completed within a deadline.

It does, however, provide an alternative educational option which, while not dominating the other methods, does seem to offer students a choice which they value. Used prudently the P.S.I. method can make a valuable addition to our arsenal of teaching techniques in economics. This contribution can either take the form of replacing certain lecture courses by P.S.I. or by adopting one or more of the P.S.I. features for incorporation into a conventional lecture course.